Chapter 1: General Introduction - molecular microbial ecology of Antarctic aquatic ecosystems

Why study Antarctic microbial ecosystems?

The Antarctica is a "cold desert" defined by constant low temperatures, little precipitation and long polar light cycles where only specially adapted organisms can survive. Life is concentrated on the few ice-free coastal oases where liquid water is present in hundreds of lakes and ponds. These include the Vestfold Hills, Bunger Hills, Larsemann Hills, Syowa Bay and McMurdo Dry Valleys in East Antarctica, the West Antarctic Peninsula and the sub-antarctic islands. Lake biota is dominated by microbial life where metazoans are rare or absent. Antarctic lakes span a wide range of physical and chemical properties from freshwater to hypersaline, ice-covered to permanently melted and stratified or mixed. Most lakes are largely isolated due to long periods of ice-cover and only receive intermittent external inputs from precipitation, glacial melt and in some cases marine incursion or animals. Permanently ice-covered lakes and the bottom waters of meromictic (permanently stratified) lakes are truly closed systems with some lakes having been isolated for thousands to millions of years. Eg. Lakes in the Dry Valleys, subglacial lakes.

Microbial communities in Antarctic lakes have reduced diversity and richness with shortened food webs. As a result, microbial processes are closely linked to lake geochemistry. As the lakes span a continuum of different environmental parameters, they present themselves as "natural laboratories" where comparisons can be made between lakes that vary in a property of interest. For example, lakes of different trophic statuses or salinities can be compared to determine adaptations to those environmental constraints. This makes Antarctic lakes ideal model ecosystems where it is possible to define the microbial community and infer the role members play within the system. Meromictic lakes similarly provide a unique opportunity to compare between the discrete zones within a single lake. The relative isolation and extreme conditions of Antarctic lakes makes them potential reservoirs of novel taxa or refuges for ancient life. This study focuses on the microbial ecology of two meromictic lakes, Organic Lake and Ace Lake located in the Vestfold Hills, East Antarctica.

The Vestfold Hills

The Vestfold Hills are a rocky ice-free region of X km (GPS) surrounding Davis Station in the Australian Antarctic Territory. They occupy the the eastern shore of the Prydz Bay. It is a temperate region and an important breeding ground for Adelie penguins, snow petrels etc.

Palaeogeography of the Vestfold Hills and the evolution of the lakes

The region was formed in the early Holocene (how long ago?) when the retreat of the continental ice-shelf lead to isostatic uplift of the land that was beneath the ice. Sea water was trapped in the rocky depressions as the peninsula rose from the sea forming the hundreds (how many?) of lakes and ponds. Most have separated from the ocean (history?) generally with the lakes further inland completely separating much earlier than the more coastal lakes. (Ages of the lakes?) All lakes were therefore originally marine derived. However, since their isolation from the ocean each lake has followed a separate physical evolution depending on the local geography and now have very different chemical and physical properties. Some have experience negative water balances have concentrated by ablation (evaporation and sublimnation) to become hypersaline such as Organic Lake. While others have a regular influx from glacial melt water or snow and salt water have become freshwater eg. Clear Lake. Nutrient status? This is the largest concentration of meromictic lake in the world (number?) and stratified basins.

Biology of the Vestfold Hills

General stuff about plants, birds, mammals, insects, microbes. Importance of viruses

Meromictic lakes and stratified basins of the Vestfold Hills

-how meromictic lakes and stratified basins form. -degrees of stratification -what occurs in each zone -recorders of climate change in the sediment and in the location of the chemocline

Limnology of Organic Lake

-hypersaline,meromictic, cold, high DMS, high external inputs -early studies -microbiota known from early microbiology -microbiota known from early molecular studies

Limnology of Ace Lake

-marine salinity, meromictic, interesting chemistrym, methanogenesis, sulfur cycle -microbiota known from early microbiology -microbiota known from early molecular studies

Insights From Molecular-based Studies of other Antarctic aquatic terrestrial

-Most study sites have used 16S or 18S rRNA gene cloning, DGGE or FISH. -Next generation studies have not been implemented. -Have studied various lakes -Have found that for some systems there is no ifference between littoral vs limnetic zones. -Can associate eutrophia with key taxa. -Can complete the Nutrient cycle in blood falls.

Key biota in the other lakes

How similar are they to the systems we're looking at?

Limitations of previous studies

Culture dependent don't look at a broad breadth of the community ignore viruses

Metagenomics and Metaproteomic approaches

Objectives

Overall, this study aimed to use metagenomic and metaproteomic approaches to gain an integrative understanding of the Ace and Organic Lake ecosystems. Using this methodology, not only can the taxonomic composition of the lakes be determined but also the functional potential of the microbial population and insight into the active members of the community. The objectives of the research were:

1) To determine the microbial and viral composition of the lake communities.
2) To determine the functional potential of the lake biota.
3) To reconstruct as much genomic information as possible of dominant taxa and to infer their physiology and ecological role.
4) To integrate environmental and biological data and model the lake microbial interactions and geochemical processes.

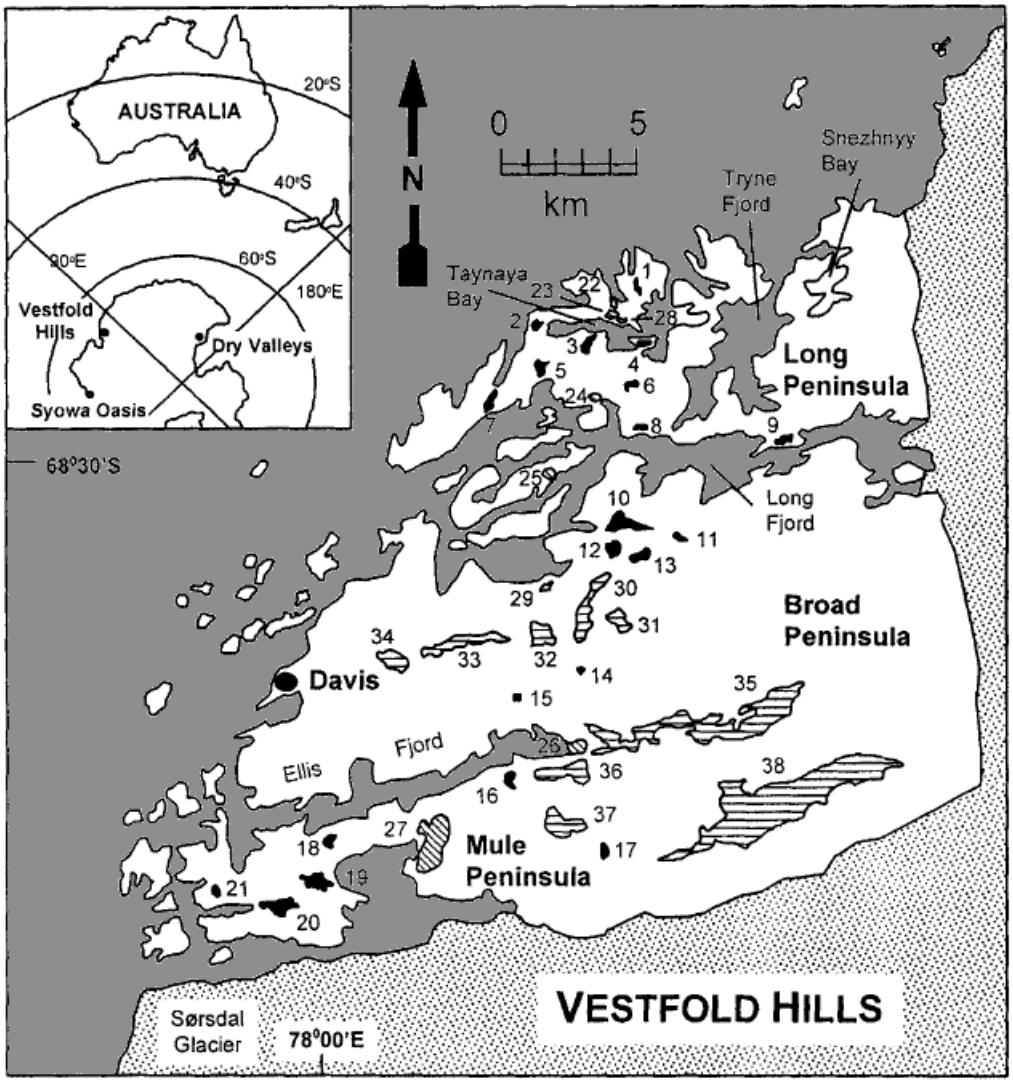

Figure 1: Map of the Vestfold Hills showing their location relative to Australia (inset). The land is shown in white, the Southern Ocean in grey, the continental iceshelf is stippled, meromictic lakes shown in black and seasonally isolated marine basins in diagonal fill. The numbered lakes and basins are: 1. unnamed lake; 2. Organic Lake; 3. Pendant Lake; 4. Glider Lake; 5. Ace Lake; 6. unnamed lake; 7. Williams Lake; 8. Abraxas Lake; 9. Johnstone Lake; 10. Ekho Lake; 11. Lake Farrell; 12. Sheild Lake; 13. Oval Lake; 14. Ephyra Lake; 15. Scale Lake; 16. Lake Anderson; 17. Oblong Lake; 18. Lake McCallum; 19. Clear Lake; 20. Laternula Lake; 21. South Angle Lake; 22. Bayly Bay; 23. Lake Fletcher; 24. Franzmann Lake; 25. Deprez Basin; 26. 'Small Meromictic Basin', Ellis Fjord; 27. Burton Lake; 28. Burch Lake; 29. Tassie Lake; 30. Club Lake; 31. Lake Jabs; 32. Deep Lake; 33. Lake Stinear; 34. Lake Dingle; 35. Lake Druzhby; 36. Watts Lake; 37. Lebed Lake; 38. Crooked Lake. Image is adapted from (Gibson 1999).